TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 401

TESTS OF N.A.C.A. AIRFOILS IN THE VARIABLE DENSITY

WIND TUNNEL. SERIES 44 AND 64.

By Eastman N. Jacobs and Robert M. Pinkerton
Langley Memorial Aeronautical Laboratory

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Summary

This note is one of a series covering an investigation of a number of related airfoils. It presents the results obtained from tests in the N.A.C.A. Variable-Density Wind Tunnel of two groups of six airfoils each. One group, the 44 series, has a maximum mean camber of 4 per cent of the chord at a position 0.4 of the chord behind the leading edge and the other group, the 64 series, has a maximum mean camber of 6 per cent of the chord at the same position. The members within each group differ only in maximum thickness, the maximum thickness/chord ratios being: 0.06, 0.09, 0.12, 0.15, 0.18 and 0.21. The results are analyzed with a view to indicating the variation of the aerodynamic characteristics with profile thickness for airfoils having a certain mean camber line form.

Introduction

A large number of related airfoils are being tested in the Variable-Density Wind Tunnel of the National Advisory Committee for Aeronautics with a view to establishing the relation between the geometric and the aerodynamic characteristics of airfoils at a high value of the Reynolds Number. The method employed to develop the airfoils having varying geometric properties is described in detail in references 1 and 2. Briefly, the profiles are obtained by combining certain thickness forms (reference 1) with several related mean camber line forms (Reference 2). The airfoils are designated by a number of four digits: the first indicates the maximum mean camber; the second, the position of maximum mean camber; and the last two, the maximum thickness.

Preliminary results already published include the tests on six symmetrical N.A.C.A. airfoils, 00 series (reference 1); the tests on the 43 and 63 series (reference 2), and the tests on the 45 and 65 series. (Reference 3.) Similar publications will follow as the tests are made.

This note presents the results of tests of two series of six airfoils each, the airfoils of each series having the same thickness forms as those of the symmetrical series (reference 1) but having curved instead of straight mean camber lines. All 12 airfoils have mean camber lines of such a form that the position of the maximum mean camber is 0.4 of the chord behind the leading edge. Six of the airfoils, the 44 series, have a maximum mean camber of 4 per cent of the chord, and the other six, the 64 series, have a maximum mean camber of 6 per cent.

Description of Airfoils

The ordinates of the N.A.C.A. airfoils with which this note deals were obtained by the method given in reference 2. The mean camber lines of these airfoils are:

	From $x = 0$ to $x = 0.4$	From $x = 0.4$ to $x = 1$
44 series	$y_c = 4/160(8x - 10x^2)$	$y_c = 4/180(1 + 4x - 5x^2)$
64 series	$y_c = 6/160(8x - 10x^2)$	$y_c = 6/180(1 + 4x - 5x^2)$

The ordinates are given in Tables I to XII, and the profile shapes are shown in Figure 1. The models, which are constructed of duralumin, have a chord of 5 inches and a span of 30 inches. The method of construction is described in reference 1.

Tests and Results

Measurements of lift, drag, and pitching moment about a point one-quarter of the chord behind the leading edge were made at a Reynolds Number of approximately 3,000,000. A description of the tunnel and of the method of testing is given in reference 1.

The results are presented in the form of coefficients corrected by the method of reference 4 to give infinite-aspect-ratio characteristics. Tables XIII to XXIV present the corrected results: lift coefficient C_L, angle of attack for infinite aspect ratio α_o, profile-drag coefficient C_{D_o}, and pitching-moment coefficient about a point one-quarter of the chord behind the leading edge $C_{m_{c/4}}$. The profile drag data are also presented in Figures 2 and 3.

Discussion

<u>Variation of the aerodynamic characteristics with thickness</u>.- The variation of minimum profile-drag coefficient with maximum thickness is shown in Figure 4. This relation may be expressed by the equation,

$$C_{D_o\,min} = 0.0065 + 0.0083t + 0.0972t^2 + k$$

where t is the maximum thickness/chord ratio. The first three terms of the above expression give the minimum profile-drag coefficient for the six symmetrical N.A.C.A. airfoils. The value of k is constant for the 44 series at $k = 0.0006$, but for the 64 series, varies from 0.0013 for the N.A.C.A. 6406 to 0.0021 for the N.A.C.A. 6421. The calculated curves, using $k = 0.0018$ (average value) for the 64 series, and the test points taken from the faired profile-drag curves (figs. 2 and 3) are shown in Figure 4.

Maximum lift coefficients taken from Figures 5 and 6 are given in the table below,

Airfoil	$C_{L\,max}$	Airfoil	$C_{L\,max}$
4406	1.23	6406	1.43
4409	1.60	6409	1.68
4412	1.61	6412	1.65
4415	1.57	6415	1.59
4418	1.47	6418	1.51
4421	1.37	6421	1.41

In agreement with the results previously published (references 1, 2, and 3), these results show that the sections of moderate thickness give the highest maximum lift coefficients.

The variation of the slope of the lift curve with thickness is shown in Figure 7. The points on the figure represent the deduced slopes for an infinite-span wing as measured in the angle of attack range in the neighborhood of minimum profile drag. It will be noted that all of the points lie below the approximate theoretical value, 2π per radian. These results are in agreement with previous results in that the lift-curve slope tends to decrease with thickness.

The pitching-moment coefficients at zero lift are given in the following table,

Airfoil	C_{m_0}	Airfoil	C_{m_0}
4406	-0.087	6406	
4409	- .086	6409	-0.133
4412	- .087	6412	- .129
4415	- .083	6415	- .125
4418	- .078	6418	- .119
4421	- .072	6421	- .110

The variation of C_{m_0} shown in the preceding table for airfoils having the same mean camber line indicates, as did the previously published results, that the value of the moment coefficient depends on the thickness as well as on the shape of the mean line of the section. It is apparent from the preceding table that, for airfoils having the same mean line, the magnitude of the diving moment decreases with increasing thickness.

The $C_{L\,max}/C_{D_0\,min}$ ratio has previously been used as a measure of the general efficiency of an airfoil section. The variation of this ratio with thickness is shown in Figure 9. It will be noted that the N.A.C.A. 4409 gives the highest value of this ratio.

<u>Variation of the aerodynamic characteristics with lift or angle of attack</u>.- The variation of profile drag coefficient with lift coefficient is shown by Figures 2 and 3. Following the procedure given in references 2 and 3, the variation of the additional drag coefficient due to lift has been studied by plotting values of $C_{D_0} - C_{D_0\ min}$ against $(C_L - C_{L\ opt})^2$ where $C_{L\ opt}$ is called the optimum lift coefficient; that is, the lift coefficient corresponding to minimum profile-drag coefficient. These plots are given in Figures 10 and 11. It is significant that the same line determined in reference 1 and used in references 2 and 3 may be used here to represent to a reasonable degree of accuracy the additional drag coefficient for the moderately thick airfoils at values of the lift coefficient less than 1. This may not be so apparent from Figure 11. However, a simple calculation shows that for a lift coefficient of 1 for the 6415 airfoil, the value of $(C_L - C_{L\ opt})^2$ is 0.44; for this and lower values the points lie reasonably close to the line. The profile-drag coefficient for the moderately thick airfoils may therefore be approximated by,

$$C_{D_0} = C_{D_0\ min} + 0.0062\ (C_L - C_{L\ opt})^2$$

$C_{D_0\ min}$ has been expressed earlier as a function of thickness.

The optimum lift coefficient varies with thickness as well as with camber, the value increasing with camber but decreasing with thickness. The values of $C_{L\ opt}$ are given in the following table,

Airfoil	$C_{L\ opt}$	Airfoil	$C_{L\ opt}$
4406	0.42	6406	0.62
4409	.36	6409	.53
4412	.30	6412	.44
4415	.23	6415	.34
4418	.17	6418	.25
4421	.11	6421	.16

The variation of the pitching-moment coefficient with angle of attack or lift may be best studied with reference to thin airfoil theory, which predicts a constant pitching moment about a point one-quarter of the chord behind the leading edge. The theory indicates that the moment about this point is constant because the center of pressure of that part of the air force which is due to angular change is at the quarter-chord point. However, the curves of $C_{m_{c/4}}$ against angle of attack (fig. 8) show a slope in the normal working range as did the corresponding curves in references 1, 2, and 3. The point of constant moment is therefore not exactly at the quarter-chord point, but displaced forward from it as indicated in the following table,

Airfoil	Displacement (per cent of chord)	Airfoil	Displacement (per cent of chord)
4406	0.2	6406	0.0
4409	.2	6409	.0
4412	.5	6412	.6
4415	1.0	6415	.9
4418	1.4	6418	1.3
4421	1.5	6421	1.8

In reference 1 the center of pressure for symmetrical airfoils is shown to be farther forward for the thick airfoils than for thin airfoils. It should be noted here that the center of pressure and the point of constant moment for a symmetrical section are coincident, as the only forces considered as acting on such a section are those due to angular change. The present results may be considered as indicating that with increasing profile thickness there is a similar progressive forward displacement of the center of pressure for that part of the air forces due to angular change.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 6, 1931.

References

1. Jacobs, Eastman N.: Tests of Six Symmetrical Airfoils in the Variable Density Wind Tunnel. T.N. No. 385, N.A.C.A., 1931.

2. Jacobs, Eastman N., and Pinkerton, Robert M.: Tests of N.A.C.A. Airfoils in the Variable Density Wind Tunnel. Series 43 and 63. T.N. No. 391, N.A.C.A., 1931,

3. Jacobs, Eastman N., and Pinkerton, Robert M.: Tests of N.A.C.A. Airfoils in the Variable Density Wind Tunnel. Series 45 and 65. T.N. No. 392, N.A.C.A., 1931.

4. Jacobs, Eastman N., and Anderson, Raymond F.: Large-Scale Aerodynamic Characteristics of Airfoils as Tested in the Variable Density Wind Tunnel. T.R. No. 352, N.A.C.A., 1930.

TABLE I

Ordinates for Airfoil N.A.C.A. 4406

(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
1.070	1.176	1.430	-0.684
2.259	1.769	2.741	- .801
4.694	2.688	5.306	- .814
7.163	3.432	7.837	- .714
9.653	4.066	10.347	- .566
14.668	5.090	15.332	- .214
19.715	5.855	20.285	.145
29.850	6.747	30.150	.753
40.000	6.901	40.000	1.099
50.059	6.536	49.941	1.243
60.101	5.836	59.899	1.276
70.122	4.828	69.878	1.172
80.116	3.528	79.884	.916
90.080	1.942	89.920	.502
95.049	1.041	94.951	.235
100.008	.062	99.992	- .062
L.E. radius	.394		
Slope of radius passing through end of chord	4/20		

TABLE II

Ordinates for Airfoil N.A.C.A. 4409
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.980	1.641	1.520	-1.149
2.139	2.410	2.861	-1.442
4.541	3.565	5.459	-1.691
6.995	4.468	8.005	-1.750
9.479	5.225	10.521	-1.725
14.502	6.418	15.498	-1.542
19.572	7.284	20.428	-1.284
29.775	8.246	30.225	- .746
40.000	8.351	40.000	- .351
50.088	7.859	49.912	- .081
60.152	6.976	59.848	.136
70.183	5.742	69.817	.258
80.174	4.180	79.826	.264
90.120	2.302	89.880	.142
95.073	1.239	94.927	.037
100.013	.094	99.987	- .094
L.E. radius	.887		
Slope of radius passing through end of chord	4/20		

TABLE III

Ordinates for Airfoil N.A.C.A. 4412
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.890	2.106	1.610	-1.614
2.018	3.053	2.982	-2.085
4.387	4.442	5.613	-2.568
6.826	5.505	8.174	-2.787
9.305	6.381	10.695	-2.881
14.337	7.742	15.663	-2.866
19.429	8.710	20.571	-2.710
29.700	9.744	30.300	-2.244
40.000	9.803	40.000	-1.803
50.118	9.182	49.882	-1.404
60.203	8.114	59.797	-1.002
70.244	6.657	69.756	- .657
80.232	4.833	79.768	- .389
90.160	2.663	89.840	- .218
95.098	1.438	94.902	- .162
100.017	.125	99.983	- .125
L.E. radius	1.576		
Slope of radius passing through end of chord	4/20		

TABLE IV

Ordinates for Airfoil N.A.C.A. 4415
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.800	2.571	1.700	-2.079
1.898	3.696	3.102	-2.728
4.234	5.317	5.766	-3.443
6.658	6.541	8.342	-3.823
9.131	7.541	10.869	-4.041
14.171	9.069	15.829	-4.193
19.286	10.136	20.714	-4.136
29.625	11.244	30.375	-3.744
40.000	11.254	40.000	-3.254
50.147	10.506	49.853	-2.728
60.253	9.254	59.747	-2.142
70.305	7.570	69.695	-1.570
80.290	5.486	79.710	-1.042
90.200	3.022	89.800	- .578
95.123	1.642	94.877	- .366
100.021	.157	99.979	- .157
L.E. radius	2.464		
Slope of radius passing through end of chord	4/20		

TABLE V

Ordinates for Airfoil N.A.C.A. 4418
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.709	3.036	1.791	-2.544
1.778	4.337	3.222	-3.369
4.081	6.192	5.919	-4.318
6.490	7.577	8.510	-4.859
8.958	8.696	11.042	-5.196
14.005	10.397	15.995	-5.521
19.144	11.563	20.856	-5.563
29.550	12.742	30.450	-5.242
40.000	12.702	40.000	-4.702
50.176	11.829	49.824	-4.051
60.304	10.395	59.696	-3.283
70.366	8.483	69.634	-2.483
80.348	6.142	79.652	-1.698
90.240	3.382	89.760	- .938
95.147	1.838	94.853	- .562
100.025	.187	99.975	- .187
L.E. radius	3.549		
Slope of radius passing through end of chord	4/20		

TABLE VI

Ordinates for Airfoil N.A.C.A. 4421
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.619	3.501	1.881	-3.009
1.657	4.980	3.343	-4.012
3.929	7.064	6.071	-5.190
6.321	8.614	8.679	-5.896
8.785	9.853	11.215	-6.353
13.840	11.720	16.160	-6.844
19.001	12.989	20.999	-6.989
29.475	14.240	30.525	-6.740
40.000	14.155	40.000	-6.155
50.206	13.152	49.794	-5.374
60.355	11.533	59.645	-4.421
70.426	9.396	69.574	-3.396
80.406	6.795	79.594	-2.351
90.280	3.743	89.720	-1.299
95.171	2.038	94.829	- .762
100.029	.219	99.971	- .219
L.E. radius	4.830		
Slope of radius passing through end of chord	4/20		

TABLE VII

Ordinates for Airfoil N.A.C.A. 6406
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.986	1.278	1.514	- .540
2.146	1.985	2.854	- .531
4.549	3.126	5.451	- .314
7.003	4.079	7.997	- .001
9.486	4.910	10.514	.340
14.507	6.283	15.493	1.029
19.574	7.337	20.426	1.663
29.776	8.618	30.224	2.632
40.000	8.901	40.000	3.099
50.088	8.480	49.912	3.185
60.152	7.610	59.848	3.056
70.182	6.323	69.818	2.677
80.173	4.633	79.827	2.033
90.119	2.547	89.881	1.119
95.073	1.357	94.927	.559
100.012	.032	99.988	- .062
L.E. radius	.394		
Slope of radius passing through end of chord	6/20		

TABLE VIII

Ordinates for Airfoil N.A.C.A. 6409
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.853	1.734	1.647	- .996
1.969	2.614	3.031	-1.160
4.323	3.987	5.677	-1.175
6.754	5.099	8.246	-1.021
9.229	6.053	10.771	- .803
14.261	7.598	15.739	- .286
19.361	8.757	20.639	- .243
29.663	10.114	30.337	1.136
40.000	10.351	40.000	1.649
50.132	9.802	49.868	1.864
60.228	8.748	59.772	1.918
70.273	7.234	69.727	1.766
80.260	5.282	79.740	1.384
90.179	2.905	89.821	.761
95.109	1.553	94.891	.363
100.019	.093	99.981	- .093
L.E. radius	.887		
Slope of radius passing through end of chord	6/20		

TABLE IX

Ordinates for Airfoil N.A.C.A. 6412
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.721	2.189	1.779	-1.451
1.792	3.243	3.208	-1.789
4.097	4.847	5.903	-2.035
6.505	6.120	8.495	-2.042
8.972	7.194	11.028	-1.944
14.015	8.909	15.985	-1.597
19.149	10.175	20.851	-1.175
29.551	11.610	30.449	- .360
40.000	11.803	40.000	.197
50.176	11.124	49.824	.542
60.304	9.886	59.696	.780
70.365	8.147	69.635	.853
80.346	5.931	79.654	.735
90.238	3.262	89.762	.404
95.145	1.751	94.855	.165
100.025	.124	99.975	- .124
L.E. radius	1.576		
Slope of radius passing through end of chord	6/20		

TABLE X

Ordinates for Airfoil N.A.C.A. 6415
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.589	2.643	1.911	-1.905
1.615	3.873	3.385	-2.419
3.871	5.706	6.129	-2.894
6.257	7.140	8.743	-3.062
8.715	8.338	11.285	-3.088
13.768	10.225	16.232	-2.913
18.936	11.593	21.064	-2.593
29.439	13.107	30.561	-1.857
40.000	13.254	40.000	-1.254
50.220	12.448	49.780	- .782
60.379	11.024	59.621	- .358
70.456	9.057	69.544	- .057
80.433	6.581	79.567	.085
90.298	3.619	89.702	.047
95.182	1.952	94.818	.036
100.031	.155	99.969	.155
L.E. radius	2.464		
Slope of radius passing through end of chord	6/20		

TABLE XI

Ordinates for Airfoil N.A.C.A. 6418
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.457	3.098	2.043	-2.360
1.439	4.501	3.561	-3.047
3.645	6.566	6.355	-3.754
6.008	8.160	8.992	-4.082
8.458	9.478	11.542	-4.228
13.522	11.540	16.478	-4.228
18.723	13.011	21.277	-4.011
29.327	14.603	30.673	-3.353
40.000	14.702	40.000	-2.702
50.265	13.771	49.735	-2.105
60.455	12.164	59.545	-1.498
70.547	9.968	69.453	- .968
80.520	7.234	79.480	- .568
90.357	3.976	89.643	- .310
95.218	2.147	94.782	- .231
100.037	.185	99.963	- .185
L.E. radius	3.549		
Slope of radius passing through end of chord	6/20		

TABLE XII

Ordinates for Airfoil N.A.C.A. 6421
(Dimensions in per cent of chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
-	-	0	0
.325	3.553	2.175	-2.815
1.262	5.130	3.738	-3.676
3.421	7.422	6.579	-4.610
5.759	9.180	9.241	-5.102
8.201	10.619	11.799	-5.369
13.276	12.850	16.724	-5.538
18.511	14.428	21.489	-5.428
29.214	16.099	30.786	-4.849
40.000	16.155	40.000	-4.155
50.309	15.093	49.691	-3.427
60.531	13.300	59.469	-2.634
70.638	10.878	69.362	-1.878
80.606	7.884	79.394	-1.218
90.417	4.334	89.583	- .668
95.254	2.345	94.746	- .429
100.043	.217	99.957	- .217
L.E. radius	4.830		
Slope of radius passing through end of chord	6/20		

TABLE XIII

Airfoil: N.A.C.A. 4406

Average Reynolds Number; 3,100,000.

Size of model: 5 x 30 inches.

Pressure, Standard Atmospheres: 20.9.

Test No.: 651 Variable-Density Tunnel. August 21, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.305	-7.0	0.0606	-0.068
- .004	-4.0	.0091	- .087
.146	-2.5	.0082	- .086
.304	-1.0	.0077	- .086
.459	.5	.0076	- .086
.610	2.1	.0081	- .084
.912	5.1	.0105	- .084
1.200	8.2	.0167	- .085
1.227	10.1	.0594	- .082
1.193	12.2	.1377	- .099
1.147	16.4	.2831	- .155
1.043	20.7	.3822	- .182
.977	26.9	.5114	- .195

TABLE XIV

Airfoil: N.A.C.A. 4409

Average Reynolds Number: 3,170,000.

Size of Model: 5 by 30 inches.

Pressure, Standard Atmospheres: 21.0

Test No.: 652 Variable-Density Tunnel. August 24, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.332	-6.9	0.0116	-0.088
- .026	-3.9	.0094	- .086
.122	-2.4	.0089	- .085
.279	- .9	.0086	- .085
.431	.6	.0086	- .084
.582	2.1	.0088	- .085
.885	5.2	.0108	- .082
1.176	8.3	.0141	- .083
1.443	11.4	.0226	- .083
1.601	14.9	.0536	- .088
1.492	17.3	.1687	- .130
1.387	19.6	.2601	- .154
1.051	26.7	.4853	- .189

TABLE XV

Airfoil: N.A.C.A. 4412

Average Reynolds Number: 3,150,000.

Size of model: 5 ~~x~~ by 30 inches.

Pressure, Standard Atmospheres: 20.8.

Test No.: 653 Variable-Density Tunnel. August 25, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.314	-7.0	0.0118	-0.088
- .008	-4.0	.0102	- .087
.140	-2.4	.0097	- .085
.300	-1.0	.0094	- .085
.453	.6	.0097	- .084
.604	2.1	.0100	- .083
.896	5.2	.0122	- .083
1.185	8.2	.0162	- .081
1.444	11.4	.0243	- .081
1.604	14.9	.0539	- .086
1.595	16.9	.1077	- .106
1.520	19.2	.1922	- .131
1.167	26.3	.4166	- .180

TABLE XVI

Airfoil: N.A.C.A. 4415

Average Reynolds Number: 3,110,000.

Size of model: 5 by 30 inches.

Pressure, Standard Atmospheres: 20.7.

Test No.: 654 Variable-Density Tunnel. August 26, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.314	-7.0	0.0123	-0.086
- .019	-3.9	.0110	- .083
.139	-2.4	.0105	- .081
.290	- .9	.0105	- .080
.443	.6	.0107	- .078
.592	2.1	.0110	- .077
.884	5.2	.0130	- .074
1.158	8.3	.0178	- .070
1.406	11.5	.0282	- .070
1.570	15.0	.0633	- .079
1.555	17.1	.1144	- .096
1.521	19.2	.1732	- .116
1.247	26.0	.3706	- .160

TABLE XVII

Airfoil: N.A.C.A. 4418

Average Reynolds Number: 3,100,000.

Size of model: 5 by 30 inches.

Pressure, Standard Atmospheres: 20.8.

Test No.: 655 Variable-Density Tunnel. August 27, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.322	-7.0	0.0135	-0.083
- .018	-3.9	.0121	- .078
.125	-2.4	.0116	- .076
.273	- .9	.0118	- .073
.426	.6	.0121	- .072
.571	2.2	.0128	- .070
.856	5.3	.0149	- .065
1.126	8.4	.0203	- .063
1.356	11.7	.0341	- .063
1.468	15.3	.0855	- .080
1.471	17.3	.1278	- .092
1.455	19.4	.1809	- .107
1.284	25.9	.3444	- .146

TABLE XVIII

Airfoil: N.A.C.A. 4421

Average Reynolds Number: 3,110,000.

Size of Model: 5 X by 30 inches.

Pressure, Standard Atmospheres: 20.8.

Test No.: 656 Variable-Density Tunnel. August 28, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.335	-6.9	0.0148	-0.078
- .045	-3.9	.0134	- .072
.099	-2.3	.0132	- .069
.245	- .8	.0133	- .067
.386	.8	.0139	- .064
.532	2.3	.0147	- .062
.805	5.4	.0180	- .057
1.065	8.6	.0251	- .055
1.279	11.9	.0451	- .060
1.360	15.7	.1035	- .077
1.371	17.6	.1419	- .088
1.374	19.6	.1869	- .099
1.361	20.7	.2149	- .105
1.238	26.1	.3334	- .134

TABLE XIX

Airfoil: N.A.C.A. 6406.

Average Reynolds Number: 3,100,000.

Size of model: 5 X 30 inches.

Pressure, Standard Atmospheres: 21.0.

Test No.: 658 Variable-Density Tunnel. August 31, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.209	-7.3	0.0935	-0.066
.136	-4.4	.0177	- .129
.295	-2.9	.0092	- .131
.449	-1.4	.0088	- .133
.607	.1	.0086	- .133
.762	1.6	.0090	- .135
1.056	4.6	.0114	- .136
1.347	7.7	.0169	- .136
1.433	9.4	.0299	- .133
1.391	11.6	.0863	- .131
1.327	13.8	.1665	- .146
1.288	15.9	.2504	- .173
1.182	20.2	.3876	- .209
1.051	26.7	.5287	- .228

TABLE XX

Airfoil: N.A.C.A. 6409

Average Reynolds Number: 3,050,000.

Size of model: 5 by x 30 inches.

Pressure, Standard Atmospheres: 20.8.

Test No.:659 Variable-Density Tunnel. September 1, 1931

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.160	-7.5	0.0130	-0.133
.146	-4.5	.0106	- .133
.299	-3.0	.0100	- .132
.456	-1.5	.0095	- .133
.610	.1	.0094	- .133
.764	1.6	.0097	- .133
1.055	4.6	.0121	- .133
1.334	7.8	.0181	- .131
1.570	11.0	.0286	- .128
1.675	14.7	.0747	- .136
1.591	18.9	.2175	- .177
1.189	26.2	.4935	- .216

TABLE XXI

Airfoil: N.A.C.A. 6412

Average Reynolds Number: 3,060,000.

Size of model: 5 ~~x~~ by 30 inches.

Pressure, Standard Atmospheres: 20.7.

Test No.: 660 Variable-Density Tunnel. September 2, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.175	-7.4	0.0129	-0.130
.131	-4.4	.0112	- .128
.283	-2.9	.0105	- .127
.439	-1.4	.0104	- .127
.592	.1	.0107	- .126
.740	1.6	.0113	- .125
1.028	4.7	.0136	- .123
1.301	7.9	.0187	- .121
1.531	11.1	.0321	- .120
1.653	14.7	.0771	- .131
1.644	16.8	.1225	- .142
1.624	18.8	.1762	- .156
1.384	25.6	.3907	- .200

TABLE XXII

Airfoil: N.A.C.A. 6415

Average Reynolds Number: 3,060,000.

Size of model: 5 by 30 inches.

Pressure, Standard Atmospheres: 20.8.

Test No.: 661 Variable Density Tunnel. September 3, 1931

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.177	-7.4	0.0135	-0.126
.129	-4.4	.0123	- .125
.279	-2.9	.0120	- .124
.428	-1.4	.0121	- .122
.581	.2	.0124	- .119
.726	1.7	.0132	- .116
1.004	4.8	.0160	- .116
1.269	8.0	.0226	- .112
1.483	11.3	.0398	- .114
1.578	15.0	.0943	- .125
1.591	16.9	.1326	- .135
1.582	19.0	.1772	- .145
1.446	25.4	.3492	- .186

TABLE XXIII

Airfoil: N.A.C.A. 6418

Average Reynolds Number: 3,100,000.

Size of model: 5 ~~x~~ by 30 inches.

Pressure, Standard Atmospheres: 20.8.

Test No.: 662 Variable Density Tunnel. September 4, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.178	-7.4	0.0144	-0.121
.123	-4.4	.0135	- .117
.270	-2.9	.0132	- .115
.417	-1.3	.0135	- .113
.561	.2	.0143	- .111
.706	1.8	.0152	- .109
.982	4.9	.0188	- .106
1.230	8.1	.0279	- .102
1.421	11.5	.0519	- .103
1.495	15.2	.1125	- .120
1.513	17.2	.1479	- .129
1.509	19.2	.1900	- .140
1.394	25.6	.3404	- .171

TABLE XXIV

Airfoil: N.A.C.A. 6421

Average Reynolds Number: 3,030,000.

Size of model: 5 X 30 inches.

Pressure, Standard Atmospheres: 20.4.

Test No.: 663 Variable-Density Tunnel. September 4, 1931.

C_L	α_o (degrees)	C_{D_o}	$C_{m_{c/4}}$
-0.199	-7.4	0.0154	-0.113
- .056	-5.8	.0149	- .111
.090	-4.3	.0146	- .108
.235	-2.7	.0147	- .105
.378	-1.2	.0150	- .103
.660	1.9	.0174	- .098
.929	5.0	.0222	- .094
1.165	8.3	.0349	- .094
1.328	11.8	.0683	- .101
1.400	15.5	.1269	- .115
1.411	17.5	.1626	- .123
1.409	19.5	.2000	- .131
1.319	25.8	.3316	- .160

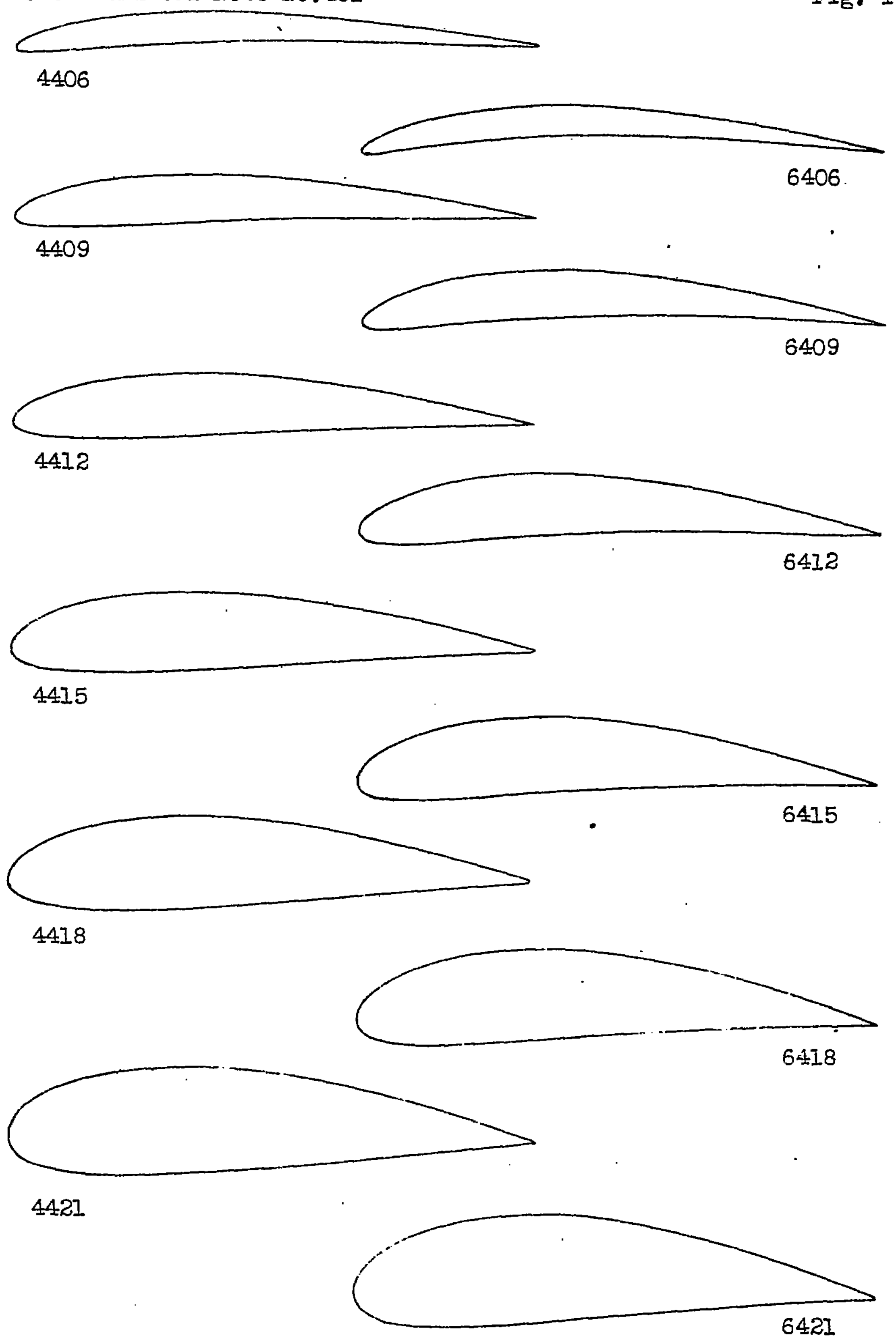

Fig.1 N.A.C.A. Airfoil profiles. Series 44 and 64

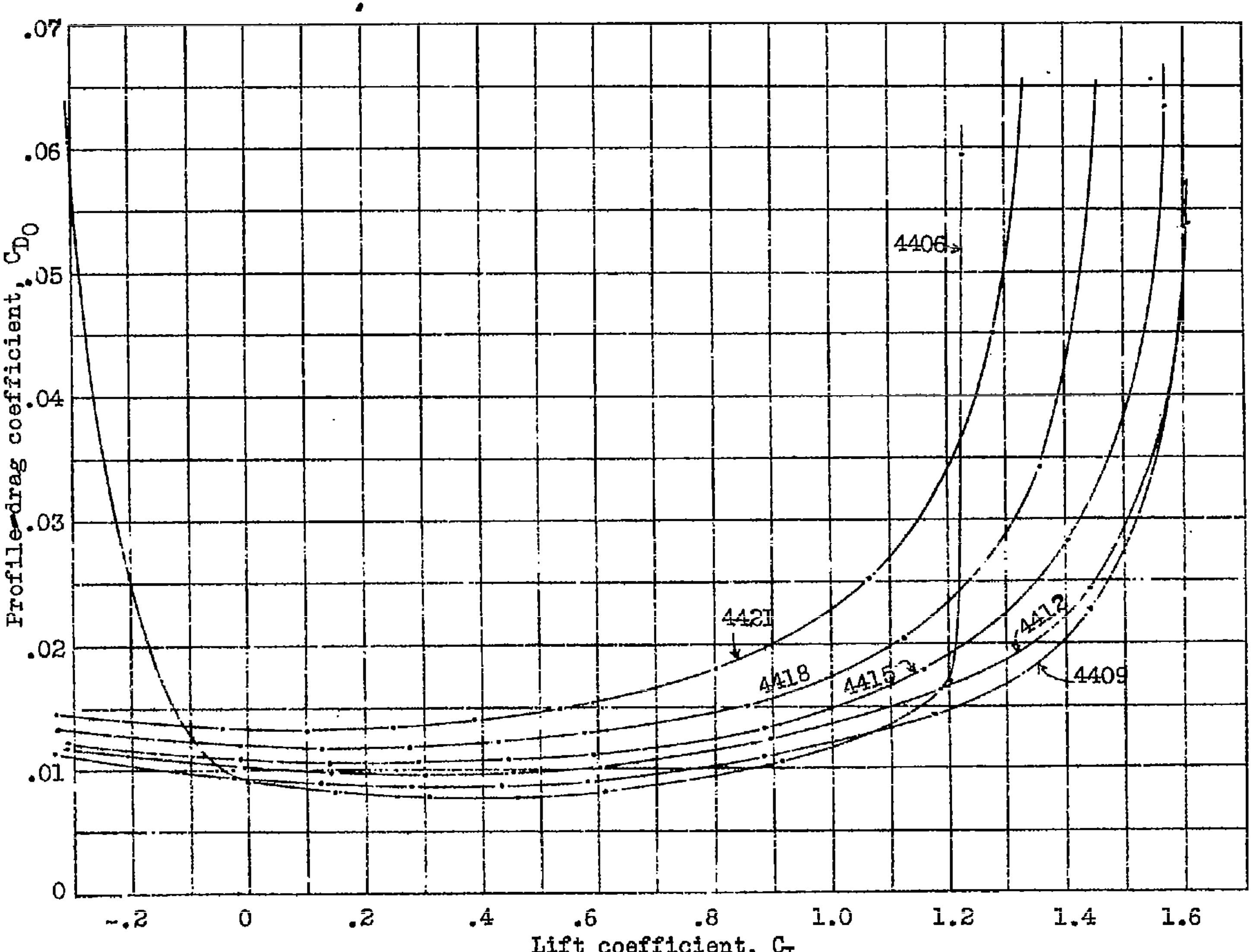

Fig.2 Profile drag curves for N.A.C.A. 44 series airfoils.

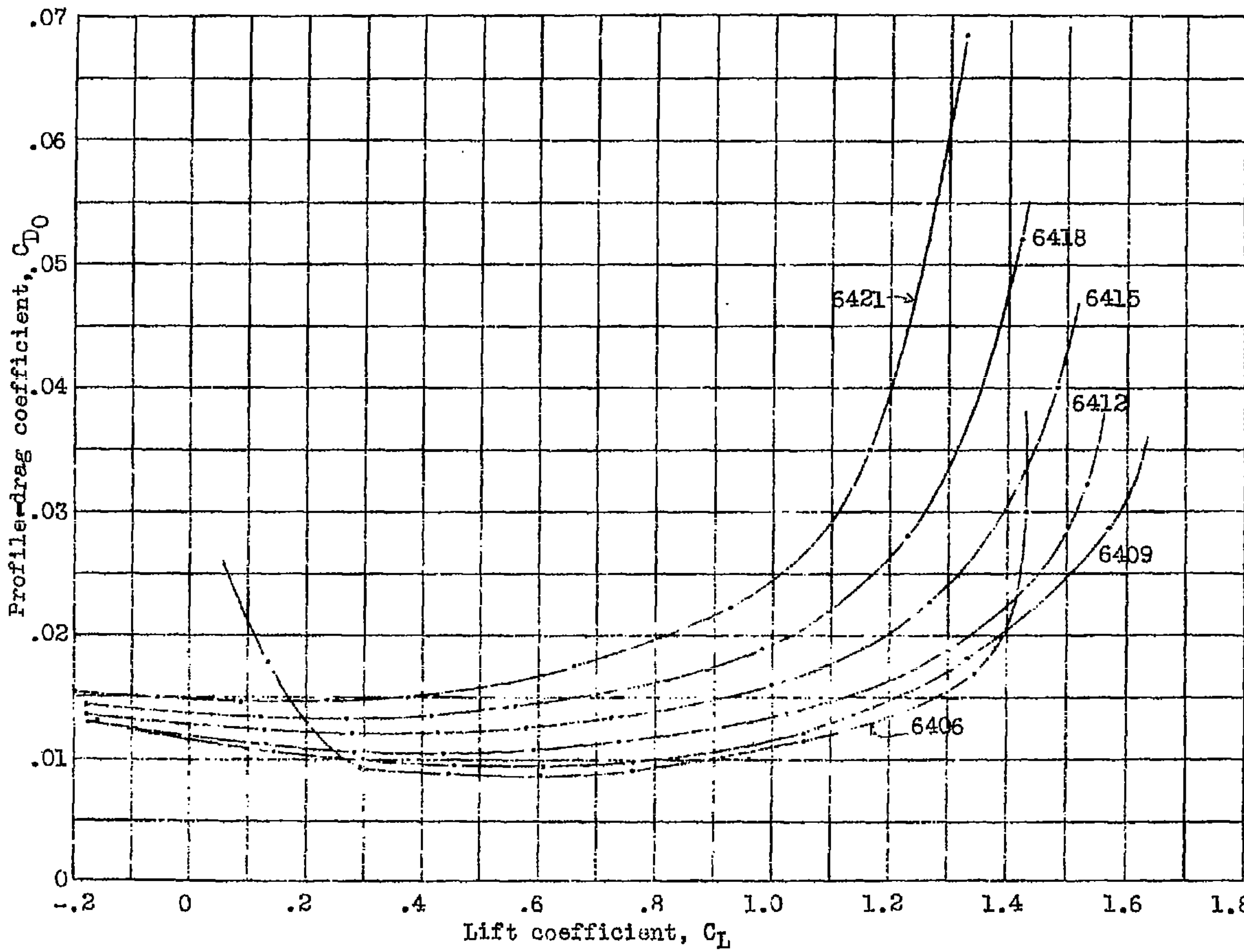

Fig.3 Profile drag curves for N.A.C.A. 64 series airfoils.

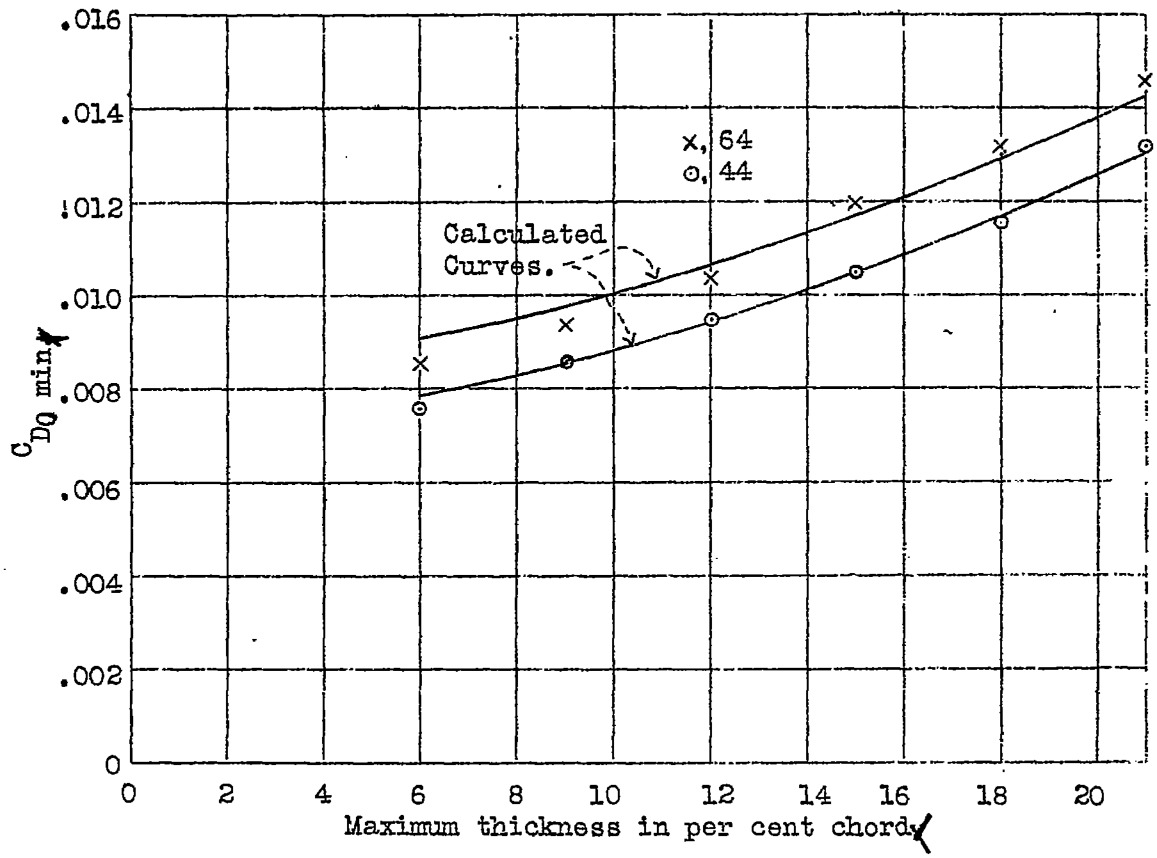

Fig. 4 Variation of minimum profile drag coefficient with thickness

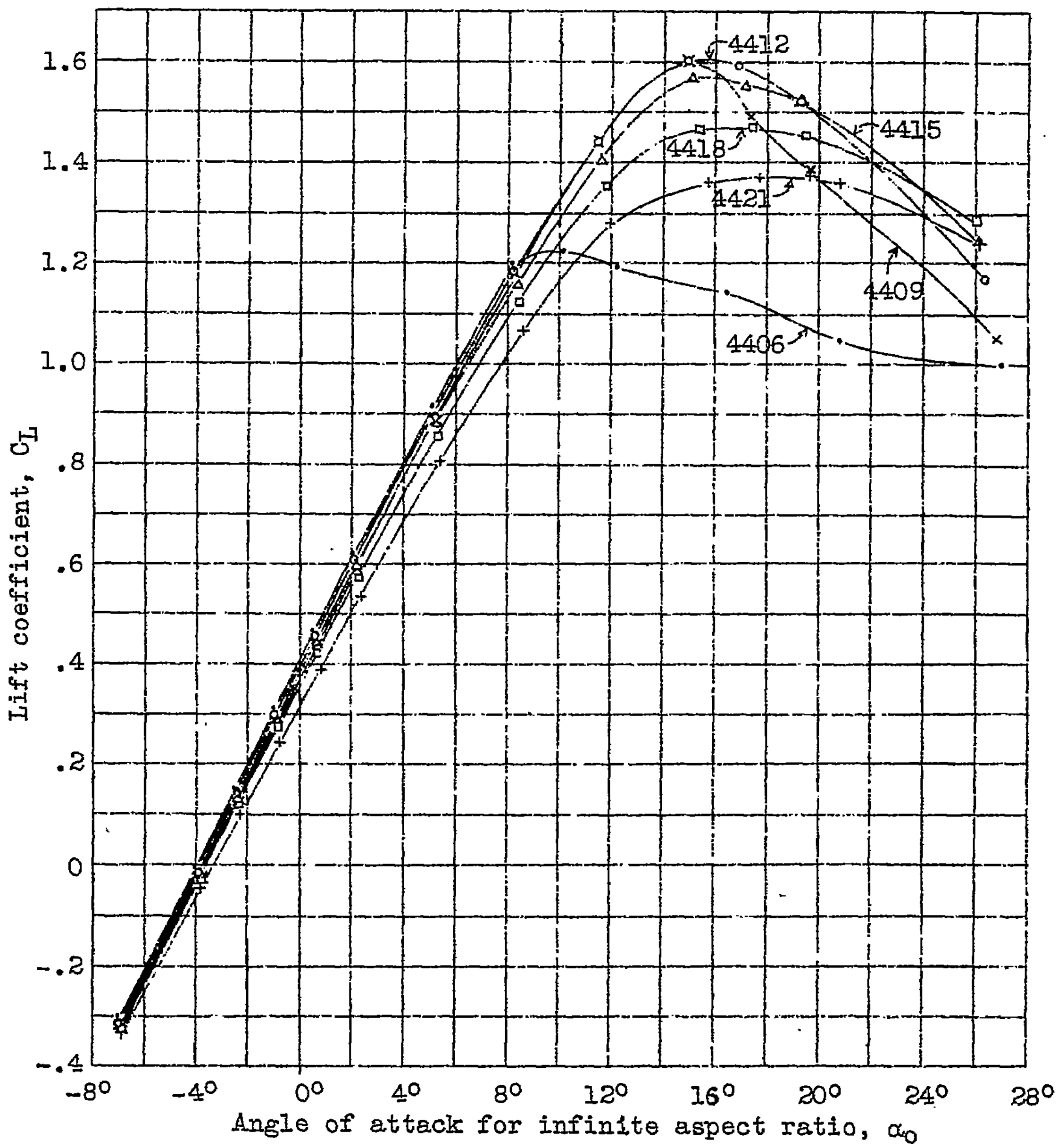

Fig. 5 Lift curves for N.A.C.A. 44 series airfoils.

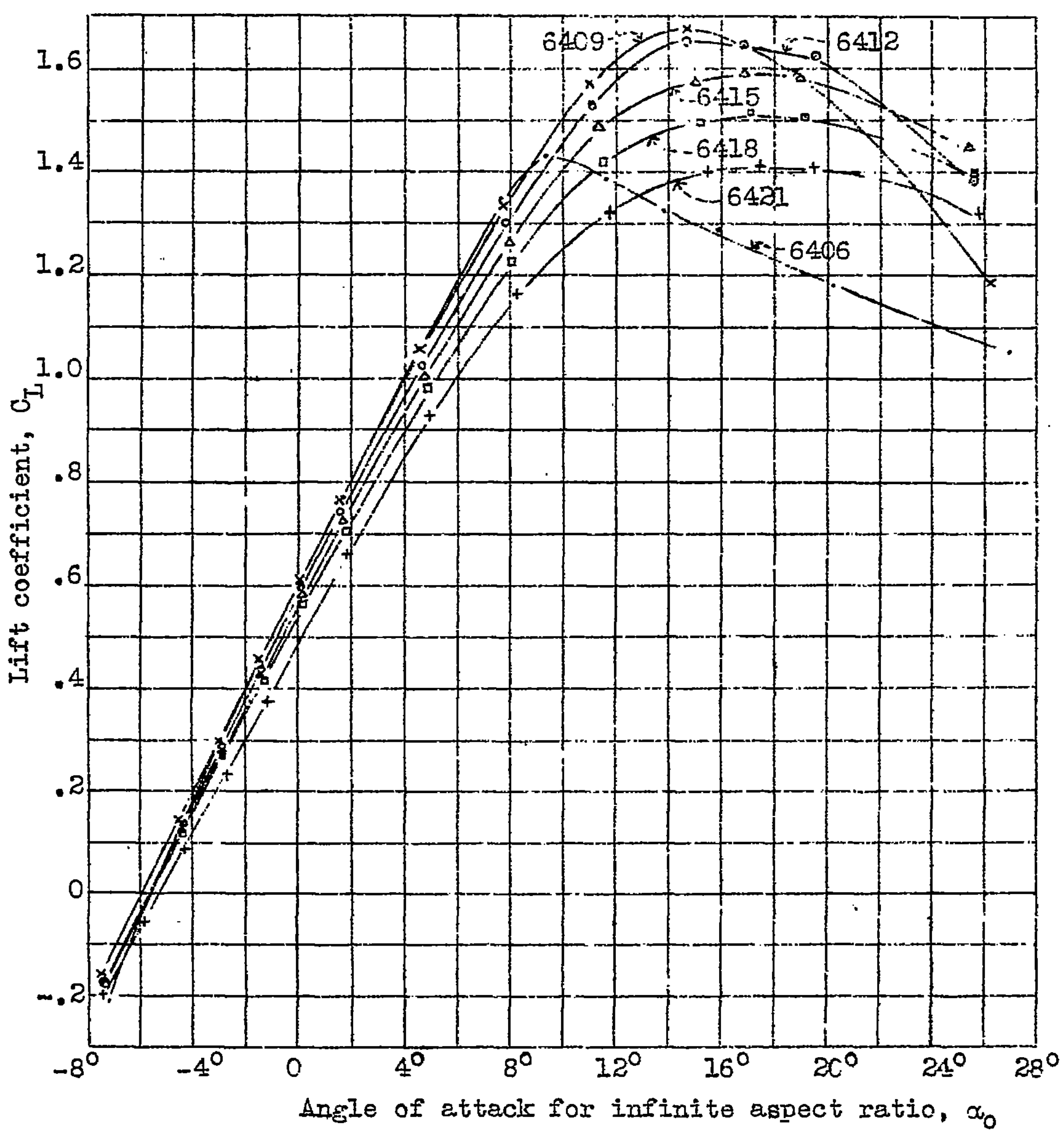

Fig. 6 Lift curves for N.A.C.A. 64 series airfoils.

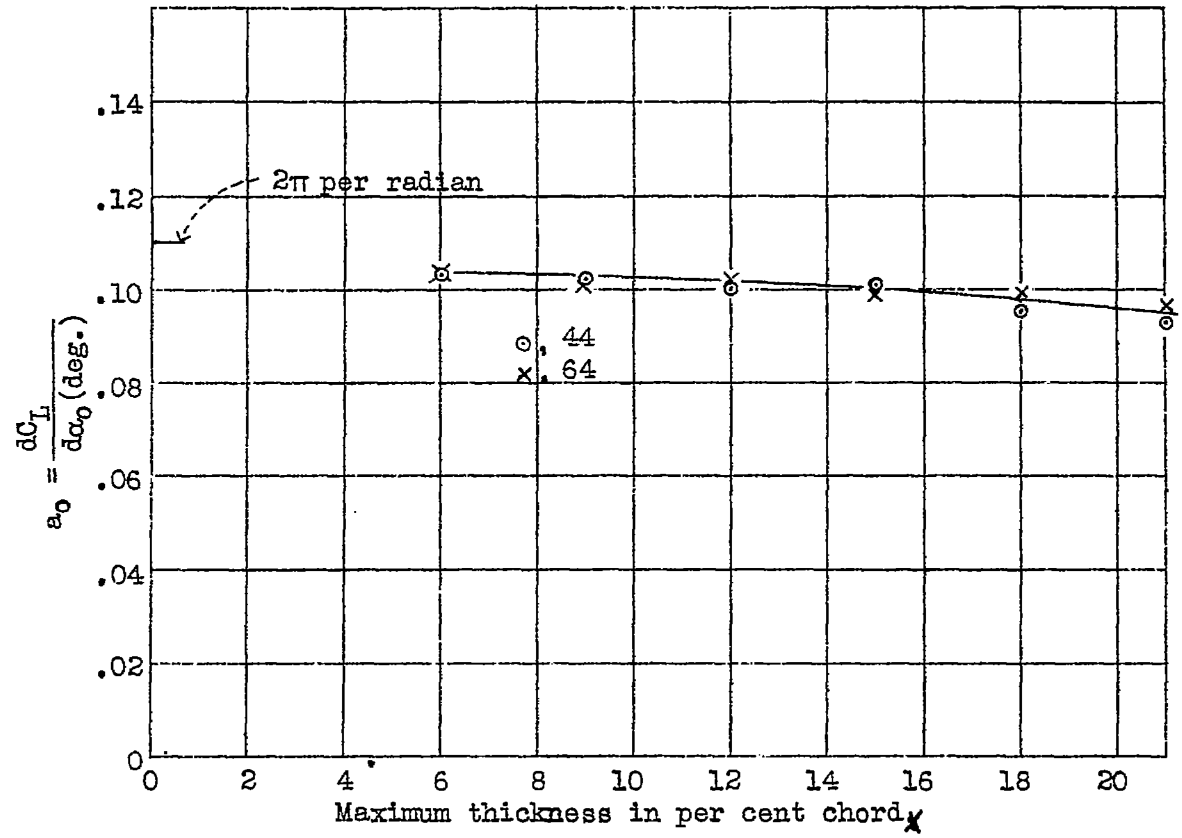

Fig. 7 Variation of lift curve slope with thickness

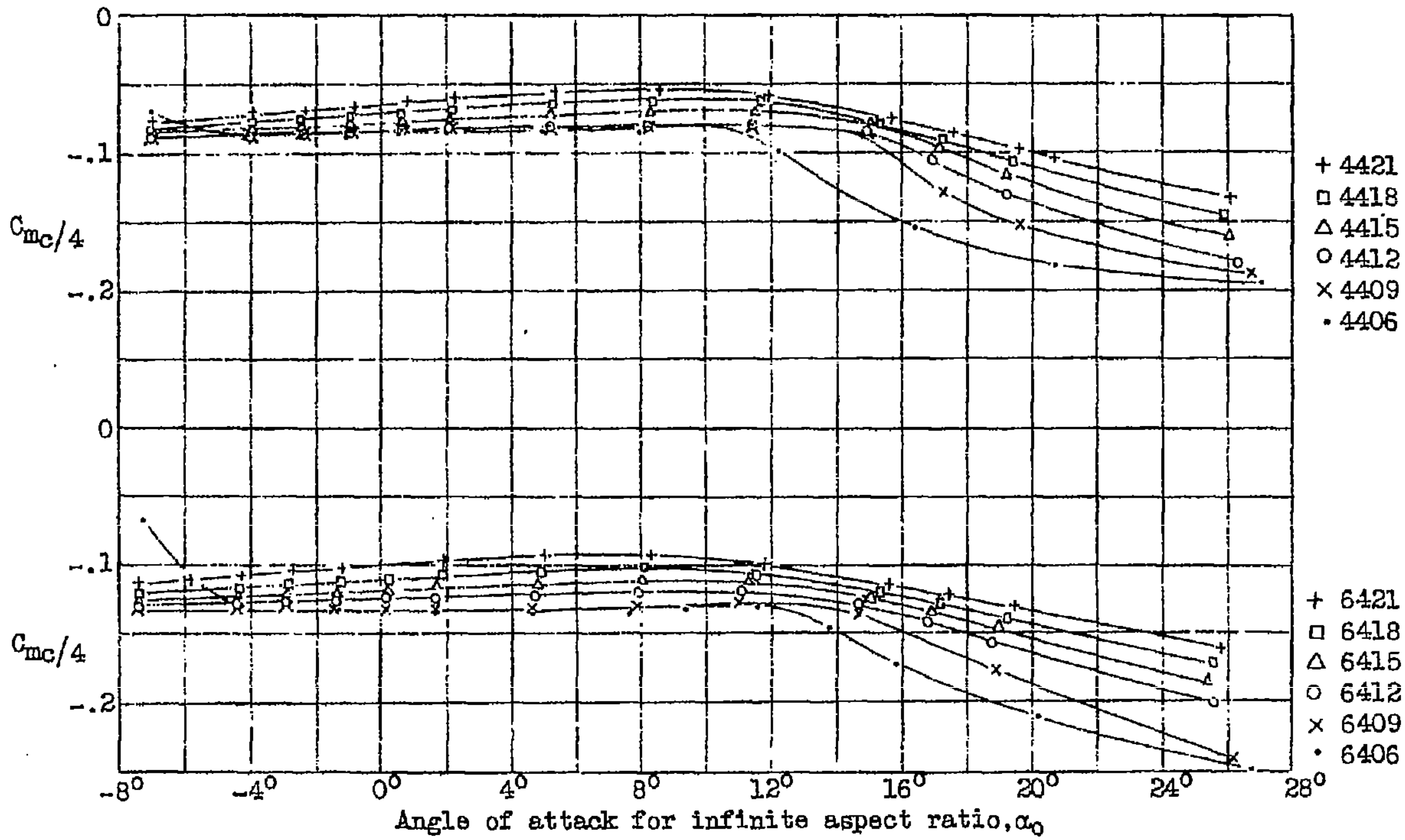

Fig.8 Moment coefficients about a point one-quarter of the chord behind the leading edge.

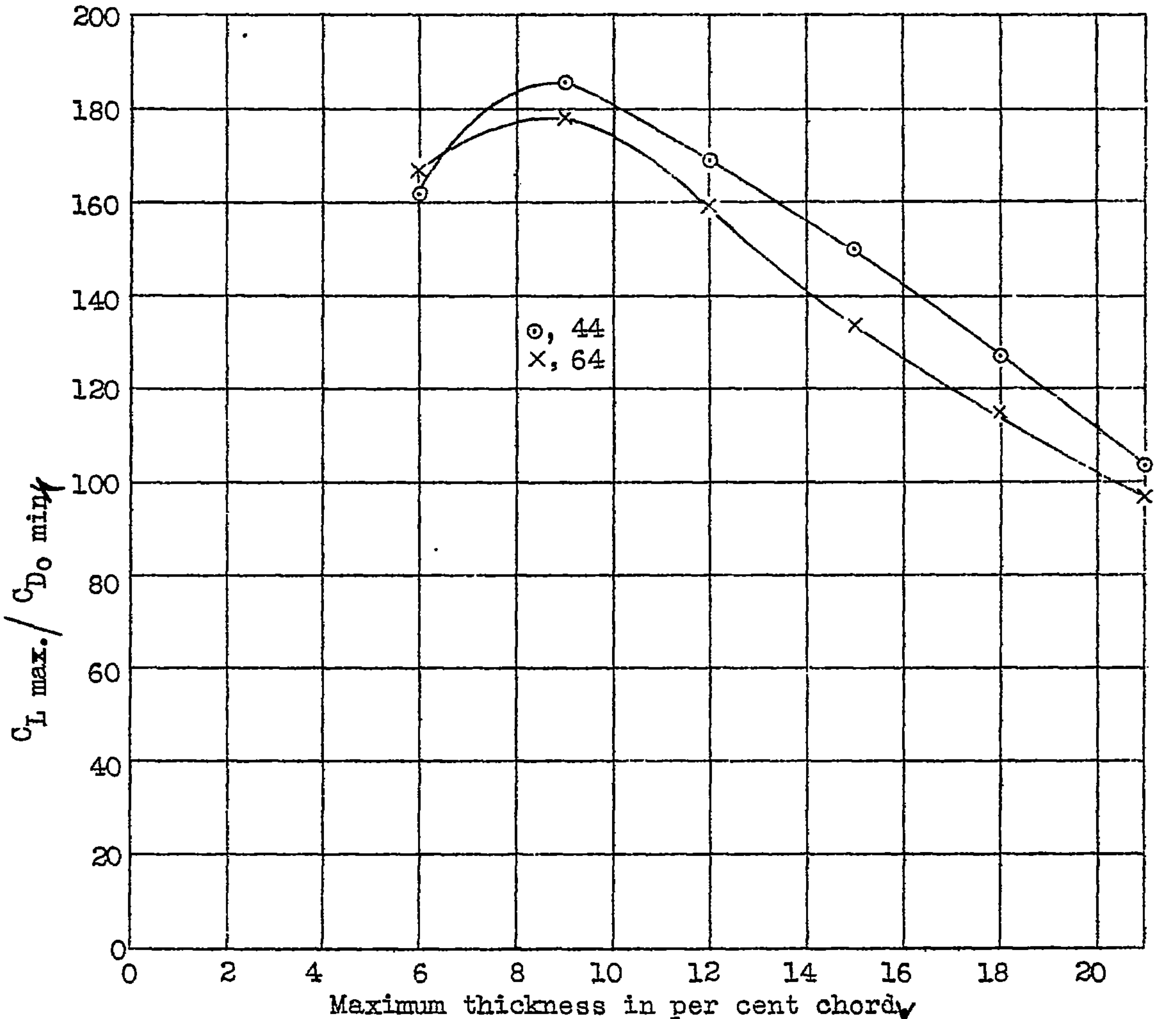

Fig. 9 Ratio of maximum lift to minimum profile drag.

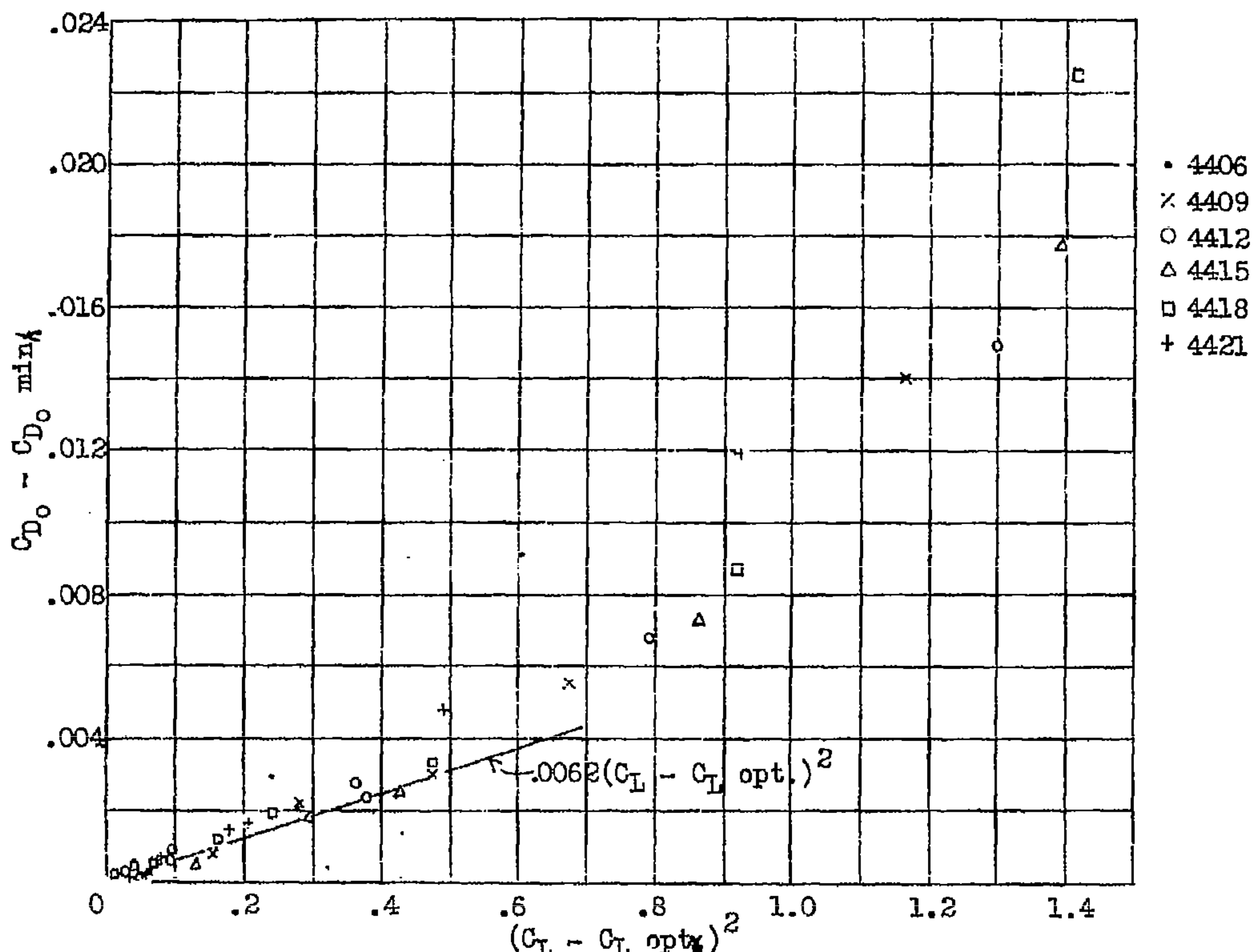

Fig.10 Increase of profile drag coefficient with lift.

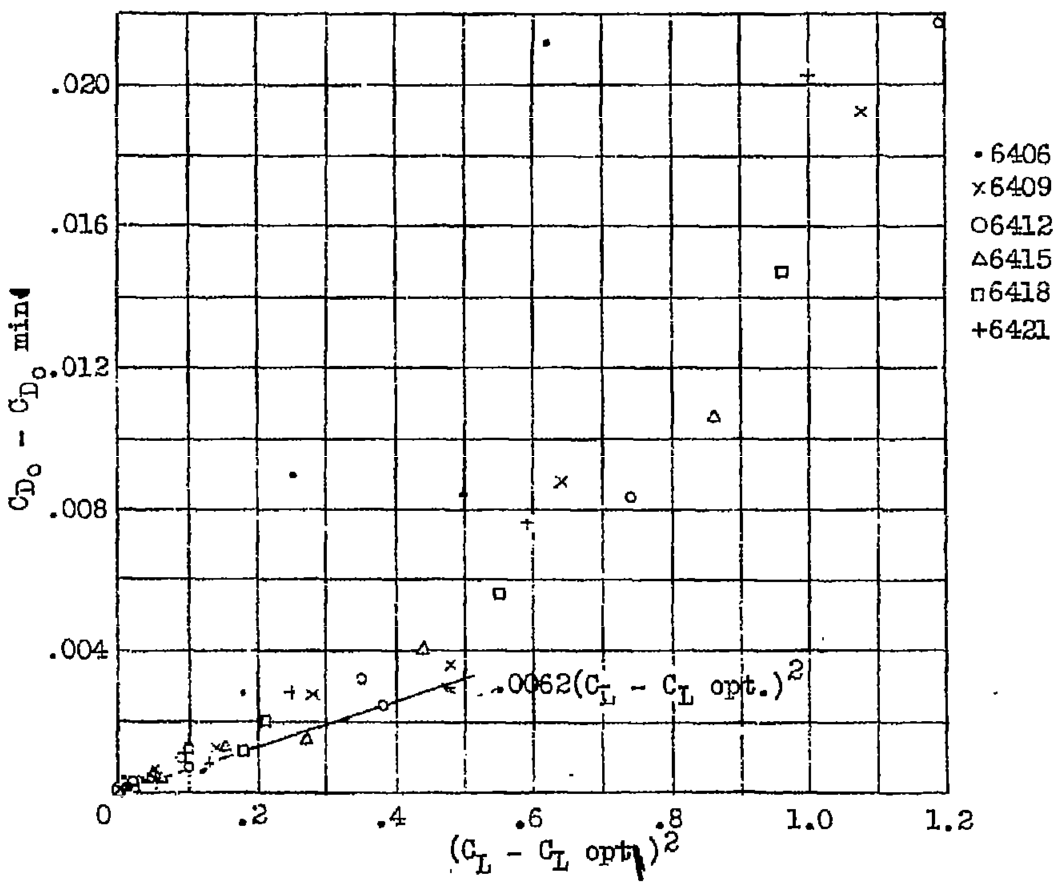

Fig.11 Increase of profile drag coefficient with lift.